

# Performance Analysis of Maintenance Using the RAM Method (Reliability, Availability, Maintainability) on the Reciprocating Compressor Unit C-4xxx at PT PSX

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## ABSTRACT

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This study evaluates the maintenance performance of the Reciprocating Compressor C-4XXX unit, which plays a crucial role in the gas production process but frequently experiences disruptions such as unplanned shutdowns, high suction temperatures, and excessive exhaust pressure. The RAM (Reliability, Availability, Maintainability) method is used with historical data from January to November 2024. The research aims to analyze the maintenance performance of the Reciprocating Compressor C-4XXX, as well as to compile proposals for improving maintenance efficiency based on quantitative data and technical analysis using the RAM method, which is expected to provide insight for the management of company as a source of information on the application of the RAM method as a basis for efforts to optimize operations and improve machine performance. The methods used are quantitative analysis of the RAM method, Pareto diagram analysis, fishbone diagram, and 5W+1H improvement proposals. The results show an average Reliability (MTBF) value of 139.50 hours, MTTR of 1.66 hours, and Availability reaching 99.24%. Pareto analysis found the main cause of high temperature pressure disturbances, and Fishbone identified factors causing problems that occurred related to worker consistency, operating conditions, lubrication systems, cooling, and controls. Improvement proposals were prepared using the 5W + 1H analysis, covering aspects of labor, methods, machines, materials, and the environment taken from the fishbone analysis carried out. By using the RAM method for companies can contribute to improving technician competency, select quality components, and improving work procedures supported using information technology.

## 1. Introduction

PT. PSX is a company engaged in exploration and production. PT. PSX functions as a surface facility. In the oil and gas, energy, and mining sectors, efficient and reliable surface facility infrastructure is key to achieving optimal production goals. Surface facilities encompass various components, from processing stations to storage and pumping systems. The operational efficiency of these facilities directly impacts productivity.

PT. PSX, as a major player in the oil and gas industry, recognizes the importance of maintaining and improving the effectiveness of its production machinery. One vital unit in gas production operations is the C-4XXX Reciprocating Compressor. Reciprocating compressors are reliable equipment typically used to distribute products to consumers through pipelines [1]. This compressor functions to increase gas pressure to meet the specifications of distribution networks or advanced processing systems. This unit operates

continuously under high loads, therefore relying heavily on effective and timely maintenance to avoid operational disruptions that risk reducing productivity.

Based on data, field observations, and interviews, during its operation, the C-4XXX Reciprocating Compressor frequently encounters a few technical problems, leading to unplanned shutdowns, which occur 15-19 times a year, and reducing the overall efficiency of the operating system. Based on operational activities obtained from field data, problems that often occur in the Compressor unit include increased temperature in the suction stage (stage suction temperature high) and high pressure in the discharge stage (stage discharge pressure high), which can indicate a disturbance in the cooling system, blockage of gas flow, or imbalance in the Compressor workload. In addition, cases of overheating in the compression cylinder also often occur, which are usually triggered by failure of the cooling system or imperfections in lubrication [2].

Several studies have shown that the operation of Reciprocating Compressors poses various potential hazards, such as oil leaks, regulator leaks, both during unit operation and during maintenance, air leaks, and unplanned shutdowns. Furthermore, there are other potential risks that have not been fully identified and measured [3]. In general, these damages stem from suboptimal implementation of preventive and predictive maintenance programs, delays in replacing critical components, and a lack of synchronization of operational procedures with actual field conditions [4]. This situation results in decreased unit reliability and an increased need for corrective maintenance, ultimately resulting in significant production downtime.

This study aims to analyze the maintenance performance of the C-4XXX Reciprocating Compressor unit and develop proposals for improving maintenance efficiency based on quantitative data and technical analysis using the RAM (Reliability, Availability, Maintainability) method. This study also uses a Pareto diagram to identify the most urgent damage, a fishbone diagram, and proposed improvements using the 5W+1H approach. This research is expected to provide insights into the management of PT. PSX, as a source of information on the application of the RAM method, can be the basis for operational optimization efforts and improved machine performance.

Corvaro, Francesco, et al., 2017. In the research in the Oil & Gas Industry, risk-based maintenance programs to improve plant safety, reliability, and availability have long been implemented. RAM is one of the risk evaluation models implemented in the Maintenance and Safety Integrity Management System [5]. Wati, Arlisa Aulia, 2020, conducted research on the analysis of Reliability, Availability, and Maintainability of reciprocating compressors at a lubricant refining company to determine how to achieve 100% maintenance [6].

## 2. Method

### 2.1 Type and Approach of Research

The type of research used is descriptive research which aims to provide a systematic, factual, and accurate description of the facts in the field, characteristics, and relationships between the phenomena studied [7].

### 2.2 Object and Scope of Research

In this context, the focus of the research is to describe the performance of maintenance activities and identify operational disturbances that occur in the Reciprocating Compressor C-4XXX unit.

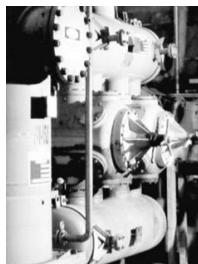


Fig. 1. Reciprocating Compressor C-4XXX unit

### 2.3 Data Collection Techniques

The data was collected through observation, interviews with supervisor and operator, surveys, collected documentation and other sources about Reciprocating Compressor C-4XXX unit.

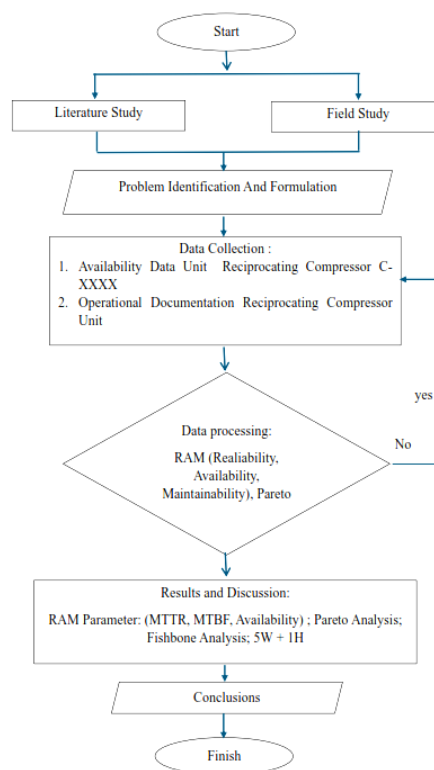
The research has a secondary data collection flow including previous data collection activities, namely company historical data, journal data, research reports, company information, and other supporting data such as procedures for collecting data information using reading and literature study methods [8] and also primary data namely machine maintenance data, and quantitative data from the Reciprocating Compressor C-4XXX unit.

## 2.4 Tools and Materials Used

In this study, the data that has been collected is then processed using an Excel program to calculate the Reliability, Availability and Maintainability of the machine.

## 2.5 Research Procedures or Stages

In this study, the research procedures can be seen in figure 2 about research flowchart.



**Fig. 2.** Research flow chart

The research flow can be seen in Figure 2, starting from literature studies and field studies to the data processing analysis process which then leads to conclusions. This diagram was created to facilitate the research being conducted.

## 2.6 Data Analysis Techniques

Secondly calculating maintenance performance with RAM analysis, thirdly creating a Pareto diagram that aims to determine the priority of problems that must be addressed immediately to improve system performance, fourthly creating a fishbone diagram to identify the root causes of the main problems that have been prioritized. Then the last one creates a 5W + 1H table to analyze and compile solutions comprehensively and directed based on the research findings.

- 1) Performance Maintenance

Performance Maintenance consists of three parts:

- a) Reliability refers to the probability that equipment will operate properly under less than ideal conditions, known as MTBF or Mean Time Between Failure [9], with formula :

$$MTBF = \frac{\text{Total Operation Time}}{\text{Shut Down Frequency}} \quad (1)$$

- b) Maintainability refers to the effort and cost incurred to perform maintenance, which can be measured by Mean Time to Repair (MTTR) [10], with formula :

$$MTTR = \frac{\text{Total Down Time}}{\text{Shutdown Frequency}} \quad (2)$$

- c) Availability refers to the proportion of time that equipment or machinery is actually ready to perform a task compared to the time it should be available for that activity [11]. With formula:

$$\text{Availability} = \frac{\text{Total Hours} - \text{Total Downtime}}{\text{Total Hours}} \times 100\% \quad (3)$$

2) Pareto Diagram

A Pareto diagram is a bar graph (histogram) that shows problems, grouped and ordered by frequency of occurrence from most to least [12]. This diagram is used to identify the relative frequency and rank the importance of various problems or causal factors. The Pareto diagram also focuses attention on critical and important issues by ranking the problems or causes of problems in terms of significance [13]. The Pareto diagram also focuses attention on critical and important issues by ranking the problems or causes of problems in terms of significance [14].

3) Fishbone Diagram

Fishbone diagrams are primarily used to identify problems and show a collection of causes and effects, known as factors, and their resulting effects, known as quality characteristics [15]. Cause-and-effect diagrams are used to explore all potential or actual causes (inputs) that produce a single effect (output) [16].

4) 5W+1H Improvement Proposal

To propose improvements to a problem, the 5W + 1H method can be applied, with an action plan that explains the allocation of resources and the implementation of the improvement development plan.

### 3. Results and Discussion

The results of the research on the performance analysis of the Reciprocating Compressor C-4XXX maintenance unit were carried out using the RAM (Reliability, Availability, Maintainability) method, which allows identification and evaluation of the level of scarcity, availability, and ease of asset maintenance, as well as its impact on operational disruptions.

Operational unit data was obtained from historical data from the Semberah Field during January–December 2023 and 2024. Data includes working hours, operating hours, scheduled and unscheduled downtime, standby time, and shutdown frequency

#### 3.1 Presentation of Research Results

##### 3.1.1 Reliability, Availability, Maintainability (RAM) Results

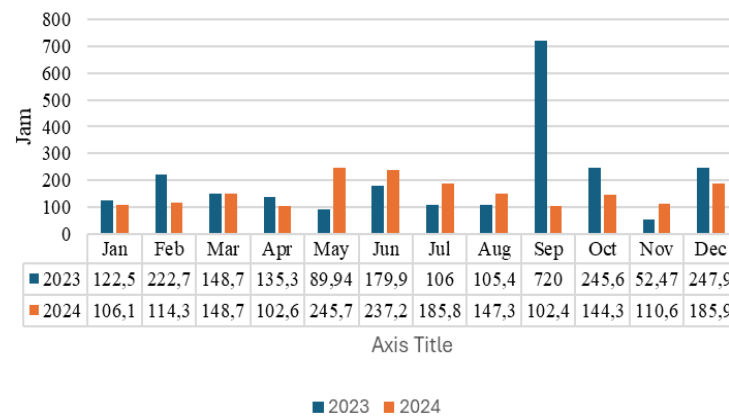
###### A. Reliability

The following Table 1 shows the MTBF calculation for the C-4XXX Reciprocating Compressor unit for January-December 2023 and 2024.

**Tabel 1.** Mean Time Between Failure

No	Month	MTBF (Hours)	
		2023	2024
1	January	122,49	106,10
2	February	222,72	114,25
3	March	148,68	148,68
4	April	135,28	102,64
5	May	89,94	245,72
6	Juni	179,88	237,22
7	July	106,04	185,78
8	August	105,42	147,33
9	September	720	102,42
10	October	245,61	144,32
11	November	52,47	110,55
12	December	247,9	185,92
Total		2376,43	1830,92

**MTBF 2023 & 2024**



**Fig. 3.** MTBF chart 2023 and 2024.

Figure 3 In November, the MTBF value for 2023 was recorded at 52.47 hours, much lower than that for 2024 which reached 140.3 hours, indicating that in 2024 the level of engine reliability increased.

#### B. Maintainability

In the MTTR calculation on the Reciprocating Compressor C-4XXX used unit January-December 2023 and 2024. The data can be seen at table 2 about MTTR

At the beginning of 2024, repair efficiency increased significantly, with January's MTTR at 0.22 hours, compared to 1.73 hours in January 2023. November 2024 also showed a significant increase, with 41.81 hours. However, there were periods when the 2024 MTTR was lowest, such as in December (0.11 hours), compared to 0.14 hours in December 2023. October 2024 recorded 5.60 hours, significantly exceeding the 3.58 hours recorded in October 2023.

**Tabel 2.** Mean Time To Repair

No	Month	MTTR (Hours)	
		2023	2024
1	January	1,73	0,22
2	February	1,92	1,90
3	March	0,15	0,15
4	April	10,90	0,26
5	May	3,50	3,42
6	Juni	0,17	4,17
7	July	0,29	0,21
8	August	0,21	1,79
9	September	0,00	0,51
10	October	3,58	5,60
11	November	3,11	41,81
12	December	0,14	0,11
Total		25,69	60,15

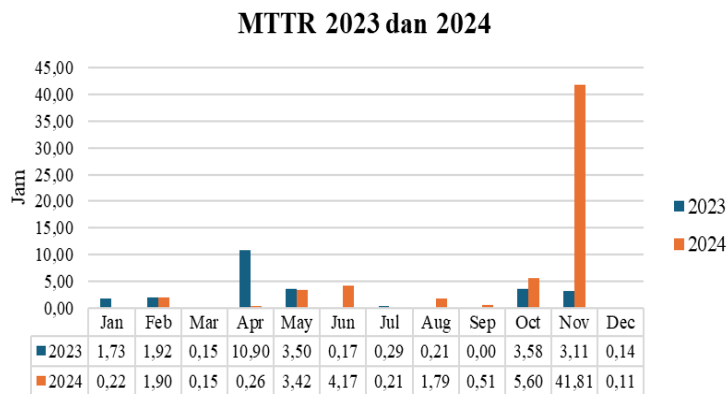


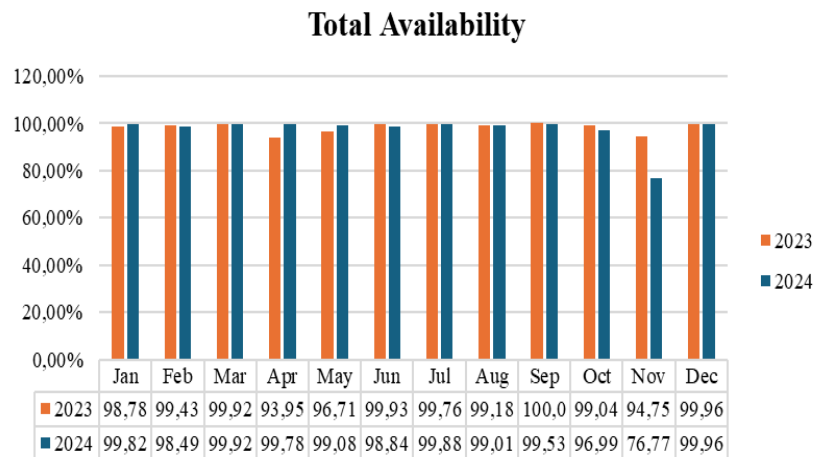
Fig. 4. MTTR Chart (2023 & 2024)

C. Availability

The following table shows the availability calculations for the C-4XXX Reciprocating Compressor unit for January-December 2023-2024.

Table 3. Availability Calculations

No.	Month	Availability (%)	
		2023	2024
1	January	98,78	99,82
2	February	99,43	98,49
3	March	99,92	99,92
4	April	93,95	99,78
5	May	96,71	99,08
6	Juni	99,93	98,84
7	July	99,76	99,88
8	August	99,18	99,01
9	September	100,00	99,53
10	October	99,04	96,99
11	November	94,75	76,77
12	December	99,96	99,96
Average		98.45	97.34



**Fig. 5.** Availability Chart

Figure 5 shows a bar graph comparing the total availability or system availability level between 2023 and 2024 for each month, from January to December. Each month displays two bars: an orange bar representing 2023 data and a blue bar representing 2024 data. Overall, 2024 showed a much more stable and higher availability performance compared to 2023. From January to September 2024, availability consistently remained above 98%.

Some months even recorded near-perfect figures, such as March (99.92%), May (99.08%), and October (99.69%). In contrast, 2023 showed a more fluctuating pattern, with several months having quite low Availability, such as April (93.95%) and November (94.75%). However, 2023 also had months with exceptional performance, such as September, which reached 100%. One of the most striking differences was seen in November, where Availability in 2024 experienced a drastic drop to 76.77%, significantly lower than November 2023, which still recorded 94.75%.

### 3.1.2 Pareto Diagram Analysis

Given the various production disruptions that occurred at the Semberah C-4XXX reciprocating compressor unit in 2023, the next step is to conduct a more in-depth classification of these disruptions. This classification is crucial for understanding the root causes, identifying priority solutions, and formulating effective and targeted repair strategies.

**Table 4.** Frequency of Operational Disruptions 2023

No	Operational Disruptions	Frequency
1	Suction/Discharge Pressure & Temp Issues	18
2	High Temperature Issue	12
3	Oil & Lubrication Issues	5
4	Alarm/Fire Detection	2
Amount		37

Based on the frequency of disruptions listed in Table 4 Pareto diagram was prepared to identify the most dominant types of disruptions in 2023, Suction/Discharge Pressure & Temp Issues with 18 frequencies.

In Figure 6, a Pareto diagram of machine disruptions during production, High Temperature Issues were recorded 12 times, indicating that high temperatures are a major cause of downtime. Meanwhile, suction/discharge pressure and temperature issues occurred 18 times, including excessively low or high suction pressure, inadequate discharge pressure, and high suction temperature. This indicates a gas flow restriction, a possible blockage, or an imbalance in the compression process. Oil & Lubrication Issues occurred five times, which can impact lubrication performance and accelerate component wear. Additionally, Alarm/Fire Detection and component replacement occurred twice, related to safety aspects and technical maintenance requirements.

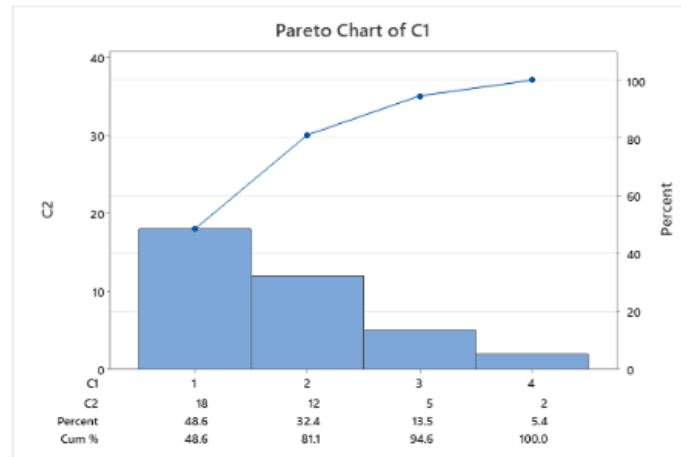


Fig. 6. Pareto diagram of machine disruptions in 2023

Each type of disruption has different operational implications, including downtime duration, potential component damage, and its impact on the overall production process. Therefore, a thorough understanding of disruption descriptions is crucial as a basis for developing appropriate mitigation measures.

Table 5. Frequency of Operational Disruptions in 2024

No	Operational Disruptions	Frequency
1	Suction/Discharge Pressure & Temp	19
2	Oil & Lubrication Issues	8
3	High Temperature Issue	5
4	Service	5
	Amount	37

Based on the frequency of disruptions listed in Table 5, a Pareto diagram was prepared to identify the most dominant types of disruptions in 2024 still was Suction/Discharge Pressure & Temp Issues with 19 frequencies.

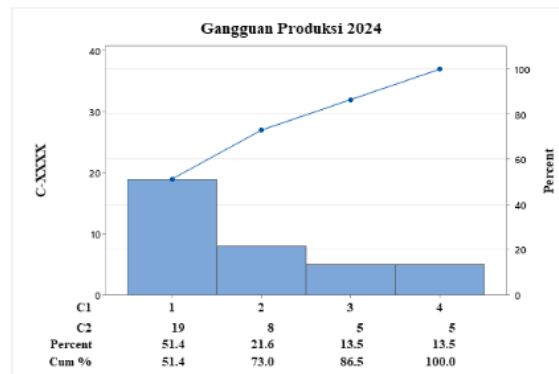


Fig. 7. Pareto diagram of production disruptions 2024

In Figure 7, a Pareto diagram of machine disruptions during production, in 2024, the most common disruptions were Suction/Discharge Pressure & Temp issues, occurring 12 times. The second most common disruption was Oil & Lubrication Issues, with 8 incidents indicating recurring lubrication issues that can impact system efficiency and pressure stability. Furthermore, there are five categories of disruptions that occur frequently: High Temperature Issues, Alarm/Fire Detection, and Component Replacement, which reflect the importance of the support and exhaust system functions in maintaining operational stability.

### 3.1.3 Fishbone Diagram Analysis

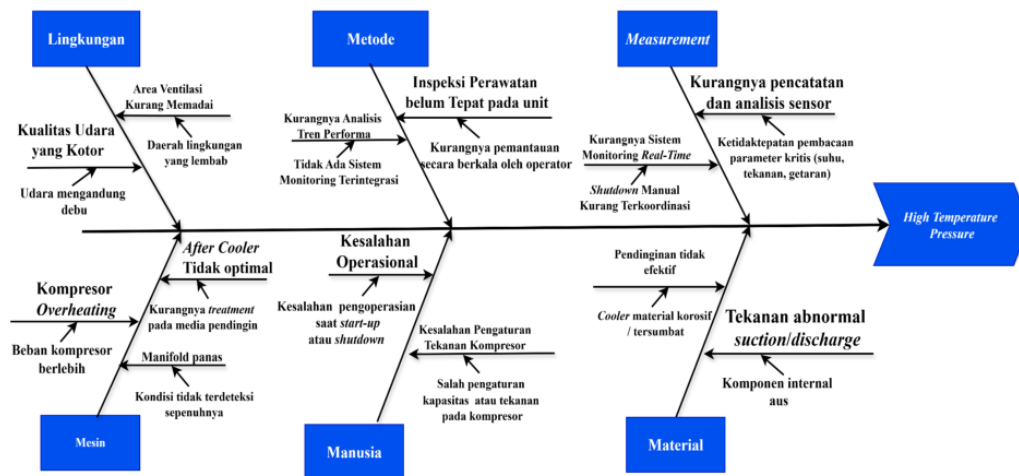


Fig. 8. Fishbone Diagram of Production Disruptions

The problems encountered were frequent compressor shutdowns and fluctuations in the MTBF value. This resulted in unstable operating systems and decreased production efficiency. To identify the causes, the causes were classified into six main categories: Environment, Method, Measurement, Material, Human, and Machine in Figure 8.

- 1) Environment: The work environment significantly impacts equipment performance, including compressors. In this case, several non-ideal environmental conditions were found: Dust, fine sand, and unstable high humidity can cause corrosion, damage electronic components, and accelerate wear.; High ambient temperatures can degrade the cooling system, causing the compressor to work harder and overheat; The exposed location of the equipment makes the compressor more vulnerable to weather disturbances, such as rain or direct heat.
- 2) Methods: Inappropriate work procedures or methods can trigger damage or worsen equipment conditions: Specific SOPs (Standard Operating Procedures) for the equipment can lead to inconsistent operation and maintenance; Work procedures are not implemented uniformly, which can lead to differences in monitoring, inspection, and problem-solving standards.
- 3) Measurement: The lack of a good monitoring and measurement system can lead to problems not being detected early: Lack of real-time temperature monitoring prevents operators from detecting temperature spikes before shutdown; Ineffective cooling is a direct cause of compressor overheating.
- 4) Material: Spare parts and materials are also a source of problems such as Poor-quality spare parts can lead to a high frequency of breakdowns; and Inappropriate material replacement times, either too late or too early, can result in inefficiency and increased risk of breakdowns.
- 5) Man such as Lack of operator training leads to a lack of understanding of how to handle or prevent damage; Lack of supervision increases the potential for errors or neglect of procedures.
- 6) Machine factors were because an outdated engine can lead to reduced performance and a greater susceptibility to damage. And the engine design may no longer be suited to current operational needs, for example, increased load requirements.

### 3.1.4 Improvement with 5W+1H

Based on the results of the maintenance and root cause analysis on the Semberah reciprocating unit C-4XXX, these indicated a high rate of manual shutdowns and high temperatures. Therefore, improvement proposals were formulated using the 5W+1H approach to develop systematic corrective and preventive actions that are adaptive to actual conditions and support increased reliability and operational efficiency of the unit.

Table 6 shows the problem-solving steps to address the disruptions, such as developing and disseminating SOPs specifically for reciprocating compressors. It's also necessary to install IoT temperature/pressure sensors integrated into the dashboard. Regular checks are required to improve machine performance and capacity.

**Table 6.** Suggested Improvements to 5W+1H

<b>PROBLEM</b>	<b>FACTOR</b>	<b>WHAT</b>	<b>WHY</b>	<b>WHERE</b>	<b>WHEN</b>	<b>WHO</b>	<b>HOW</b>
<i>High-Temperature</i>	Method	Special SOP for use Compressor not properly operated system	Inspection schedules are not consistently implemented.	Work area and Operator Room	During operation and maintenance	Operator and Supervisor	1. Develop and disseminate a specific SOP for compressors. 2. Add a digital checklist integrated with a reminder system.
	Measurement	Lack of real-time temperature monitoring	Manual measurement is ineffective and not real-time.	Control panel & operator station	When the machine is operating	Operator, Tim control & Supervisor	IoT temperature/pressure sensor installation integration to dashboard
	Material	Use of non-standard spare parts	Material quality does not meet OEM specifications	Gudang & maintenance area	Components replace	Procurement Team, Operators & Supervisors	1. Ensure the use of OEM parts. 2. Validate spare part vendors, perform material testing, and review technical specifications before purchasing.
	Man	Operators lack understanding of procedures	Lack of technical training	Field & control room	Operation & inspection	Operator & Supervisor	1. Create a troubleshooting module and conduct live simulations in the field. 2. Develop SOPs and operations manuals in visual and report form.
	Machine	Intercooler cooling system evaluation and upgrade	Ineffective cooling, causing high temperatures and trips	Compressor installation location	During high load or continuous operation	Operator & Supervisor	1. Evaluate current engine performance and capacity 2. Audit coolant performance, check for fouling or damage to the heat exchanger, and repair or replace if necessary.
	Environment	The air quality around the unit is dirty (contains dust)	Lack of air quality control systems and optimal temperature & humidity settings	Compressor Installation Location	When the unit is operating	Operator & Supervisor	Conduct regular checks on the shelter to reduce humidity and add ventilation.

In 2024, it can be said that there has been an increase in the effectiveness of C-4XXX Reciprocating Compressor engine maintenance. This is beneficial for maintaining the continuity of engine operation. With the calculation of Reliability, Availability, and Maintainability (RAM), the RAM method can be considered by companies because it is effective in providing performance overviews and repair priorities based on historical data. Manual shutdowns due to engine service and high temperatures at suction/discharge.

#### 4. Conclusion

The calculation results show that the Mean Time Between Failure (MTBF) value increased from 1,656.43 hours in 2023 to 1,830.92 hours in 2024, while the Mean Time to Repair (MTTR) also increased from 25.69 hours to 60.15 hours. The average Availability Level of 98.52% in 2023 and 97.36% in 2024 reflects that the implemented maintenance system is quite optimal. Pareto analysis identified dominant disturbances in the form of manual stoppages due to routine maintenance (engine servicing), as well as high temperature disturbances in the suction and exhaust stages, which significantly affect operational performance. To improve performance, improvements are made by strengthening Preventive and Predictive Maintenance procedures using the RAM method in the company, so that it can contribute to improving technician competence and selection. To improve performance, improvements are made through strengthening preventive and predictive Maintenance procedures using the RAM method to the company, so that it can contribute to improving technician competency, selecting quality components, and improving work procedures supported using information technology. The 5W + 1H approach which is also obtained through interview studies with sources in the field, this analysis is used to formulate comprehensive actions as a strategy to improve the reliability and effectiveness of the maintenance system in a sustainable manner such as in the method factor, a sustainable SOP is needed in its implementation, in the measurement factor, the use of IOT sensors is needed on the machine, analysis of the material factor shows that the use of spare parts must be monitored for availability so that when replacements are needed there are no time constraints for ordering. Human factors, continuous socialization of SOPs are required. From an environmental perspective, regular checks on work areas such as shelters need to be carried out to reduce humidity, one way of doing this is by adding ventilation.

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